Journal of Environment Sciences (2024), **Volume X**, 1-9
https://doi.org/10.3126/jes.v10i1.66902

Comparison of Vermicomposting Quality using Different Food beds

Ganga Shrestha[1,3*], Sushila Gwachha[2], Mohan Bikram Shrestha[3]
[1] Central Department of Environmental Science, Tribhuvan University, Kathmandu,
[2] Department of Environmental Science, Tribhuvan University, Kathmandu
[3] Wildlife Research and Education Network (WREN), Kathmandu, Nepal
*Correspondence: shresthaganga080@gmail.com

Abstract

Organic waste management has been one of the great problem in urban areas. Among various efforts carried for managing the organic waste, vermicomposting is one of the efficient efforts that have been effectively applied in household and community level. Studies on vermicomposting process have proved vermicompost is quality compost with higher percentage of nutrient contents. However, based on the solid waste types and organic materials available in the waste, comparative study on the vermicompost is limited. This study was carried out to compare vermicompost quality using different organic wastes as food beds. A research was carried out at Madhyapur Thimi, Bhaktapur using cow dung, tea leaf, vegetables and their combination as food substrates. 100 gm of Red worms (*Eisenia foetida*) was used. Different parameters such as pH, Moisture content, Electrical Conductivity (EC), Organic Matter (OM), C: N ratio, Nitrogen (N), Phosphorus (P) and Potassium (K) were analyzed. Positively strong correlation was found between electrical conductivity and potassium whereas negatively strong correlation found in nitrogen and C:N ratio. There is found to be have a significant difference in parameters between different treatments. However, all are effective compost producing quality nutrients among which vermicompost with tea leaf possess high nitrogen and phosphorus, while combination of vegetable and cow dung gave high potassium value.

Keywords: *Eisenia foetida*, nutrient value, organic waste

Introduction

Growing urbanization and population growth has not only increase solid waste generation, but also increase challenges for its management. Due to lack of appropriate technical team, people's participation and resources, it has been remained as an unsolved topic. In recent years, concept of reuse and recycle is approaching to deal with the solid waste of Kathmandu Valley. Among which, Vermicomposting is also one of them and it is gaining its momentum as can be initiated by household to enterprise level. Vermicomposting is an environmental friendly technology used in solid waste management which has two ways advantage: it helps in management of organic waste and the worm cast can be used as vermicompost, useable forms of compost without any adverse impacts to soil, plant and environment (Gheisari et al., 2009; Mehta & Karnwal, 2013). It involves joint action of earthworms and mesophilic microbes (Benitez et al., 1999). The main aim of vermicomposting is to increase number and weight of worms and convert substrate material into vermicompost in shortest duration and highest recovery as possible (Rupani et al., 2013).

Earthworm acts as a mechanical blender by grinding organic matter and increasing surface area exposing to microorganisms (Yadav & Garg, 2011). During composting processes, the micronutrients present in the feed materials are converted through microbial action into forms that are more soluble and available to plants than those in parent substrate (Kaushik & Garg, 2003). Therefore, vermicompost enriches soil with microorganisms which improves soil texture, structure, nutrient retention, water-holding capacity and aeration (Shrivastava & Singh, 2013). Therefore, increase in germination and plant growth from 50-100% over conventional compost and 30-40% over chemical fertilizers is the main success of this simple method degrading by over 75% faster than conventional systems (Sinha et a., 2010). The nutrient analysis (Aryal & Tamrakar, 2013; Bajal et al., 2019) and humic substances (Dominguez et al.,

1997) also found to be better in vermicompost than other types of composting. It also reduces proportion of water soluble chemical which causes less possible environmental contamination (Mitcheell, 1997). Some study showed phenolic substances produced in this method causes the plant's resistance against pathogens (Hanc & Vasak, 2015). Further, use of vermicompost is relatively free from odor and pathogens especially the coliforms therefore can be used in indoor plants too.

Different species of earthworm are used in this process such as *Eisenia foetida*, *Eisenia anderi*, *Lumbricus rebellus*, *Epiges, Endoges* etc of which *Eisenia foetida* is commonly used in our country (Devkota et al., 2014). This species of worms has high growth rate, early sexual maturity and extensive reproduction (Devi et al., 2012). Along with selection of worm's species, selection of substrate materials and their combination for bedding purpose and worm food sources plays important role to optimize vermicomposting efficiency, influence the activity of worms and alters the quality of manure formed (Jafarpour et al., 2017; Manaig, 2016). In the world, studies have used different food beds like cattle manure, chicken manure (Manaig, 2016), cow dung, kitchen waste, foliage waste (Das et al., 2014), water hyacinth, paddy straw and sawdust (Das et al., 2016), waste rose flower (Daman et al., 2016), tea leaves mixed with cow dung (Kaur et al., 2014), mixed vegetable waste with soil (Shah et al., 2013), sewerage sludge mixed with composted cow dung (Ludibeth et al., 2012) and rice bran with food waste (Pourzamani & Ghavi, 2016) whereas Elephant dung, Rhino dung, litter, garbage (Dhimal et al., 2013) , vegetables wastes (MGN/JICA, 2005), agricultural wastes like *Lantana camara, Ageratum conyzoides*, banana pseudo stem, garden waste, vegetable waste, mycostraw cow dung (Bajal et al., 2019) was used in our country. However, use of cow dung, tea leaf, vegetables and their combination for quality analysis are really scarce. Vegetables, tea leaf and cow dung are common organic waste released in our community. Therefore, this study aims to compare vermicompost quality using different food beds. Specific objectives include to know the time period of formation of vermicompost and to analyze physical and chemical parameters.

Material and Methods

The experimental set up was designed in author's home: Madhyapur Thimi, Bhaktapur from February-March, 2018. Vermicomposting process was carried out in following steps:

Methods

Vermi bin set up with food substrates: Seven rectangular container having similar dimensions of 14×18 inches was used. Bedding was prepared from newspaper (2 bundle) and wet straw (20 gm) in each bin. Bedding provides comfy living material for worms. Food sample of different ratios (150gm) was used in each set up container. The three major food substrates i.e. cow dung, vegetable waste (green leafy vegetable mostly mustard leaf) and dry used tea leaf were used. Pre-composting was not done for any food substrate but partially decomposed cow dung was used as fresh cow dung may be harmful to heating process. Below table shows the combination of food substrate (Table 1).

Table 1: Combination of food beds

Sample No.	Combination of food beds
1	Cow dung only (CD)
2	Vegetables only (V)
3	Tea leaf only (TL)
4	Tea leaf and cow dung (1:1) (CD:TL)
5	Tea leaf and Vegetables (1:1) (TL:V)
6	Vegetables and cow dung (1:1) (V:CD)
7	Tea leaf, Vegetables and cow dung (1:1:1) (CD:V:TL)

Introduction of worms: Red worms (*Eisenia foetida*) weighing 100 grams was introduced (Fig. 1). The pile was covered with jute soaked with water to maintain moisture and to avoid direct light and flies. The mixtures were turned manually every 2 days for 10 days to increase aeration.

Feeding worms: Feed (450gm) to worms was added after 2 days of set up followed with 600gm feed after a week. Additional 300gm foods was added in sample 2 (tea leaf) and sample 5 (tea leaf and cow dung) due to prompt composting process (Fig. 2).

Harvest the compost: After seven weeks of composting process, the foods substate turned into deep, dark brown and earthy-looking material. It is loosely crumbly at the top of bed and consider it as vermicompost. Prior to harvest, compost was refrained from watering for one week to ease the separation of castings from worms and preventing the castings to become compact.

Figure 1: Weighing of Red worms (Eisenia foetida)

Figure 2: Vermicompost bin set-up

Data Analysis

Physio-chemical parameters of vermicompost such as Soil pH, electrical conductivity, moisture content, organic matter and C: N ratio were analyzed in lab of Khwopa College whereas for the available forms of NPK analysis, samples were sent to MIRON Laboratory and Research Center in Kathmandu. Among the total portion of nutrients NPK, only certain portion is readily available for the plants to use. For example, in case of phosphorus the amount of P available to plants is generally not exceeded 0.01% of the total phosphorus (Kayastha, 2014).

Below table 2 shows parameters along with methods for each parameter. One-way ANOVA was used to test for significant differences among treatments. The data were entered and analyzed in MS-excel.

Results and Discussion

Time period for the formation of the compost

Out of seven samples of vermicomposting, six of them were harvested while remain one do not formed compost (Fig. 3). The time period to harvest was about 7 weeks (Fig. 4) which is quiet similar with Shah et al. (2013) i.e. following 50 days when used mixture of sewerage sludge with cow dung. Average days for vermicompost to formed is from 42 to 70 days when prepared using elephant dung and rhino dung (Dhimal et al., 2013). Pourzamani and Ghavi (2016) formed pleasantly earthy, granular nutrient rich vermicompost after 30 days when used rice bran and food waste. Sample having vegetables only (Sample 3) caused mortality of worms, may be due to lack of pre-composting (Frederickson et al., 2007). Since it releases turbid water during decomposition process that may cause souring

Table 2: Parameters and methods adopted for the laboratory analysis of vermicompost samples

S.N.	Parameters	Unit	Methods
1	Soil pH		pH meter
2	Electrical conductivity	µS/cm	Conductometry
3	Moisture content	%	Oven-dry method (Jackson, 1967)
4	Organic matter	%	Walkley and Black method (Walkley & Black, 1934)
5	C:N ratio		
6	Nitrogen	%	Kjeldhal Method (Bremner& Mulvaney, 1982)
7	Phosphorus	%	Olsen's Method (Olsen et al., 1954)
8	Potassium	%	Flame Photometer (Okalebo et al., 2002)

environment to the composting environment that may stressed earthworms causing to death. Therefore, either doing pre composting first and or using cow dung supplementation 50% or more in the feed help to solve this problem (Asadollahfard & Mohebi, 2012; Garg & Gupta, 2011; Huang et al., 2013). Adopting the concept of High-rate Vermireactor operation which was quenched by use of soil with phytomass is very successful to achieve sustainable vermicomposting of vegetable waste without any pre composting or cow dung supplementation (Shah et al., 2013).

Figure 3: Freeze and death worms in Sample No.3

Figure 4: Researcher harvesting compost

Change in physical and chemical parameters of vermicompost

There showed the significant differences in parameters ($P<0.05$; p=2E-14) among the different food beds (Table 3). Other researchers also have similar findings (Bajal et al., 2019; Chaulagain et al., 2017; Kaur et al., 2014; Ludibeth et al., 2012). The below table (Table 3) shows statistical analysis using one-way ANOVA test in Ms-Excel.

Positively strong correlation was found between electrical conductivity and potassium whereas

Table 3: One-way ANOVA table between parameters in different food beds

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	45882083	7	6554583	31.40852	2.49E-14	2.249024
Within Groups	8347522	40	208688			
Total	54229605	47				

Table 4: Correlation between physical and chemical parameters

	pH	EC	Organic matter	Moisture	C:N ratio	Nitrogen	Phosphorus	Potassium
pH	1							
EC	.563	1						
Organic matter	-.367	.408	1					
Moisture	-.234	-.173	.098	1				
C: N ratio	-.247	.331	.244	.555	1			
Nitrogen	.249	-.342	-.282	-.580	-.998**			
Phosphorus	.181	-.593	-.615	-.100	-.560	.569	1	
Potassium	.333	.944**	.535	-.186	.379	-.389	-.810	1

**. Correlation is significant at the 0.01 level (2-tailed).

negatively strong correlation found in nitrogen and C: N ratio. Positively moderate correlation was found in pH and EC, C: N ratio and moisture content, nitrogen and phosphorus and organic matter and potassium. Negatively moderate correlation was found in nitrogen and moisture content, phosphorus and electrical conductivity, organic matter and phosphorus, C: N ratio and phosphorus and phosphorus and potassium. The correlation table is shown in Table 4.

During the examination of vermicompost's, the pH ranged from 7.49 to 8.12 indicating that the composts are alkaline in nature and is similar with Aryal and Tamrakar (2013) i.e 7.6. pH value is near neutral which might be due to secretion of NH_4^+ ions that reduce concentration of H^+ ions and catalytic fixation of CO_2 as $CaCO_3$ by carbonic anhydrase in the earthworm's gut (Haimi & Huhta, 1987; Pattnaik & Reddy, 2010). The research done by other researchers are within our range: Muthukumaravel et al. (2008) have 8.3 in vegetables vermicompost while 7.9 in cow dung. Chaulagain et al. (2017) gives 7.4 in cow dung whereas HMGN/JICA (2005) reported 8 in vegetables wastes. pH is increased in tea leaf than in tea leaf+cow dung i.e. from 7.76 to 7.49 which is similar with study of Kaur et al. (2014). The pH ranged from neutral to slightly alkaline is best for crop production (S et al., 2013).

The highest electrical conductivity (EC) of the vermicompost was 3999 µS/cm. The lowest was 1158.67 µS/cm in tea leaf which is similar with Kaur et al. (2014). EC generally estimates the soluble salt concentration in soil and commonly used as measure of salinity. Sample 2 have low EC because it releases less salt such as potassium (0.19 %) during vermicomposting process. The reason of low EC might be due to utilization of soluble salts by micro-organisms for the microbial biomass (Yadav & Garg, 2011) and also due to absorption of soluble salts by earthworms and enhanced microbial activities (Kumar & Singh, 2001). However, in case of sample 5, sample 6 and sample 7, there is high release of salt i.e. potassium than other samples due to mixing of two or more food substrate types and hence high in EC. The reason for equal EC in these samples is due to almost equal release of potassium %. (sample 5: 0.7 %, sample 6: 0.85 % and sample 7: 0.78 %). The range are similar with other findings (Chaulagain et al., 2017 gave 3780 µS/cm in cow dung; Mousavi et al., 2017 i.e. 8940 µS/cm the highest and the lowest 2310 µS/cm for vermicompost from food wastes, rotting foliage and cow dung).

Moisture content ranged from 64.8% to 69.3% which is higher than Dhimal et al. (2013): 24.93% and 30.66% in elephant and rhino dung respectively and nearly similar with HMGN/JICA (2005) i.e 58.70% in vegetable waste. Aryal and Tamrakar (2013) also have 62.5% in vermicompost. The moisture content having value 60-70% was proved to having maximal microbial activity (Liang et al., 2003).

Organic matter was found to be maximum in sample 7(10.16%) which may be due to mixture of three food substrate: tea leaf, cow dung and vegetables. While in sample 2 (only tea leaf), the organic matter was minimal i.e. 8.77. However, very low when comparing with other studies. In the experiment done by Dhimal et al. (2013), it is found to be 26.915 and 26.9425 in rhino dung vermicompost and elephant dung vermicompost respectively which is more than double with our findings. Also, research by Ludibeth et al. (2012) have range of 70.02% to 47.32% when used sewerage sludge as food beds which is not equivalent with our findings. Aryal and Tamrakar (2013) also have high value i.e. 31.49. This implies that among different criteria for producing efficient compost, various aspects play important role and selection of raw composting material is major one in determining nutritional composition such as organic matter (Chandna et al., 2013; Confesor et al., 2009).

The C: N ratio is mostly used indexes of organic waste maturity: higher the value, slow the rate of decomposition (Christopher, 1996). In this study, it ranged from 1.21 to 2.86. The finding is very lower than other researchers (Aryan & Tamrakar, 2013; Mahaly et al., 2018). This means the vermicompost formed from above used food substrates tend to have a fast rate of decomposition when applied to the soil and act as nitrogen fertilizers than others food substrates (Yadav et al., 2017).

The gut of earthworm plays important role in converting organic residue to plant available macronutrients such as nitrogen, phosphorus and potassium in vermicomposting process. Also, acid production during decomposition by microorganisms converts these nutrients into its respective soluble forms (Lee, 1992; Sharma, 2003). Significantly higher nitrogen content suggested the high composting ability of worms which range from 0.1% to 4% or even more (S et al., 2013). The high nitrogen content is found in sample 2 (4.22%) which may be due to high nitrification rate in which ammonium ions converted into nitrates (Dominguez, 2004). The lowest is in sample 1 (1.83 %). However, mixing any other plant materials along with cow dung was found better in terms of percentage of nitrogen after sample 2 (Bajal et al., 2019) which is similar with our findings too. In the research done by Muthukumaravel et al. (2008), the value of nitrogen in Vegetable waste- Cow dung was 1.76% and 1.62% in cow dung. The report of HMGN/JICA (2005) value 0.62% whereas 2.55 % to 1.86% ranges in different proportion of sewerage sludge and cow dung vermicompost (Ludibeth et al., 2012). Chaulagain et al. (2017) have percentage range of 0.19% to 0.23%. when used cow dung and other banana pseudo stem, leaf litter and saw dust.

The available phosphorus ranges from 0.92% to 1.66% and highest found in sample 2 (only tea leaf). Euras et al. (2009) found high phosphorus over the initial substrate from cow manure, followed by aquatic weeds, grasses and municipal waste. The obtained value of P is quite similar with Muthukumaravel et al. (2008) i.e. Vegetable waste+Cow dung – 1.60% and 1.20% in cow dung. However, found less in HMGN/JICA (2005) with the value of 0.84% and, Aryal and Tamrakar (2013) with value 0.70%. Also, low phosphorus was found in Unito (2023) (0.2% to 0.4%). In this study, potassium ranged from 0.19% to 0.85%. which is similar with Chaulagain et al., 2017 (ranged from 0.42% to 0.63%). The available potassium is highest in sample 6 (vegetables and cow dung) and low in sample 2 (tea leaf only). Higher potassium value was found in sewage sludge vermicompost of Delgado et al. (1995). In the article of Aryal and Tamrakar (2013), the potassium content of vermicompost was found to be 4.99% using the domestic waste which is higher than this study. HMGN/JICA (2005) gave the value 3.49% with vegetable waste and 4.98% and 2.65% in vegetable waste + cow dung and cow dung only in Muthukumaravel et al. (2008). Value of potassium in Unito (2023) have a range of 0.46% to 1.18%.

The summarized values are shown in below (Table 5).

Conclusion

According to the result of present experiment, the survival of compost worms in food bed having only vegetables was not possible. The final vermicompost was pleasantly earthy in odor, granular, nutrient-rich, much darker in color, and more homogeneous than initial materials after 7 weeks by *Eisenia foetida* earthworm activity. There were significant differences in the tested parameters when used different food beds. However, food bed with tealeaf give more nitrogen and phosphorus content whereas potassium is high in vegetables+cow dung. Also, the vermicompost quality results are quite similar with prior vermicomposting findings. The results from

Table 5: Summary of physical and chemical analysis of Vermicompost

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
pH	7.93	7.76	-	7.49	8.12	7.84	7.7
Electrical Conductivity(µS/cm)	3057.67	1158.67	-	1598	3999	3999	3999
Organic Matter (%)	8.99	8.77	-	9.75	9.46	9.27	10.16
Moisture Content (%)	68.3	64.8	-	69.3	66.6	66.3	65.3
C:N ratio	2.86	1.21	-	2.51	1.49	2.85	2.33
Nitrogen (%)	1.83	4.22	-	2.26	3.7	1.89	2.54
Phosphorus (%)	1.52	1.66	-	1.2	1.32	0.92	1.15
Potassium (%)	0.44	0.19	-	0.37	0.7	0.85	0.78

the casting analysis (in all food beds) had revealed that the organic wastages can be converted into usable form with its nutrient release. And, hence it is considered to be a potent organic fertilizer for sustainable agricultural practices.

Acknowledgements

I love to provide sincere gratitude to Khwopa College for providing Laboratory facility. Also, I would like to thank MiRON Laboratory and Research Center, Tinkune for testing the compost samples. I am grateful to Ms Hisila Sijakhu, Faculty member of Khwopa College for providing partial funding to this research. Further, I would like to thank Mr Prabin Shrestha and Mr Sudeep Duwal for assisting me during vermicompost set up and experiment.

References

Aryal, J., & Tamrakar, A.S. (2013). Domestic Organic Waste Composting in Madhyapur Thimi, Bhaktapur. *Nepal Journal of Science and Technology*, 14,129-136.

Asadollahfardi, G., & Mohebi, A. (2012). Fruits and Vegetables Residue Vermicomposting using Earthworm *Eisenia fetida*. *Journal of International Environmental Application and Science*, 7(2),261-265.

Bajal, S., Subedi, S., & Baral, S. (2019). Utilization of Agricultural Wastes as Substrates for Vermicomposting. *Journal of Agricultural and Veterinary Science*, 12,79-84.

Benitez, E., Nogales, R., Elvira, C., Masciandaro, G., & Ceccanti, B. (1999). Enzyme activities as indicators of the stabilization of sewage sludges composting with Eisenia foetida. *Bioresource Technology*, 67,297-303.

Bremner, J.M., & Mulvaney, C.S. (1982). Nitrogen total. In: Page, A.L. (editor) *Methods of soil analysis. Agron. No. 9, Part 2: Chemical and microbiological properties. 2nd edition.* Am. Soc. Agron., Madison, WI, USA, 595-624.

Chandna, P., Nain, L., Singh, S., & Kuhad, R.C. (2013). Assessment of bacterial diversity during composting of agricultural products. *BMC Microbiology*, 13,1-14.

Chaulagain, A., Maharjan, B., Pathak, R., Piya, S., Chimoriya, S., Shrestha, I., Gauchan, D.P., & Lamichhane, J. (2017). Effects of feeding materials on yield, quality of vermicompost, Multiplication and Reproduction of Eisenia foetida. *Journal of Science, Engineering and Technology,* 13,15-25.

Christopher, M.S.M. (1996). Recycling of plantation agro wastes. *Planters Chron*, 91,53-61.

Confesor, R., Hamlett, J., Shannon, R., & Graves, R. (2009). Potential pollutants form farm, food and yard waste composts at differing ages: Leaching potential of nutrients under column experiments. Part II. *Composting Science Utility*, 17,6-17.

Daman, R., Singh, K.K., & Singh, B. (2016). Determination of micronutrients in vermicompost prepared with waste rose flower *(Rosa berberia*) collected from religious places of Patna. *Research Journal of Chemical and Environmental Sciences Res J. Chem. Environ. Sci*, 4(5),37-43.

Das, D., Bhattacharyya, P., Ghosh, B.C., & Banik, P. (2016). Bioconversion and biodynamics of Eisenia foetida in different organic wastes through microbial enriched vermiconversion technologies. *Ecological Engineering*, 86,154-161.

Das, D., Powell, M., Bhattacharyya, P., & Banik, P. (2014). Changes of carbon, nitrogen, phosphorous, and potassium content 606 during storage of vermicompost prepared from different substrates. *Environ Monit Assess*, 186,8827–8832.

Delgado, M.M., Bigeriego, I., Waiter., & Calbo, R. (1995). Use of California red worm in sewage sludge transformation. *Turrialba*, 45,33-41.

Devi, G.S., Karthiga, A., Susila, S., & Muthunarayanan, V. (2012). Bioconversion of fruit waste into vermicompost by employing *Eudrillus eugeniae* and *Eisenia foetida. International Journal of Plant, Animal and Environmental Sciences*, 2(4),245-252.

Devkota, D., Dhakal, S.C., Dhakal, D., Dhakal, D.D., & Ojha, R.B. (2014). Economics of production and marketing of vermicompost in Chitwan, Nepal. *International Journal of Agricultural and Soil Science (ISSN: 2315-9989)*, 2(7),112-117.

Dhimal, M., Gautam, I., & Tuladhar, R. (2013). Effectiveness of vermicomposting in management of organic wastes using *Eisenia Foetida* and *Perionyx Favatus* in Central Zoo Jawalakhel, Nepal. *J. Nat. Hist. Mus*, 27,92-106.

Dominguez, J. (2004). State of the art and new perspective on vermicomposting research. *Earthworm Ecology*, C.A. Edwardss (Ed.), CRC Press LLC, 401-424.

Dominguez, J., Edwards, C., & Subler, S. (1997). Comparison of vermicomposting and composting. *Biocycle,* 38,57-9.

Euras, A. (2009). Earthworms Vermicompost: A powerful crop nutrient over the conventional compost and protective soil conditioner against the destructive chemical fertilizers for food safety and security. *Journal of Agricultural and Environment*, 14-55.

Frederickson J., Howell G., & Hobson A.M. (2007). Effect of Pre-composting and vermicomposting on compost characteristics. *European Journal of Biology,* 43,320-326.

Garg, V.K., & Gupta, R. (2011). Optimization of cow dung spiked pre consumer processing vegetable waste for vermicomposting using *Eisenia fetida*. *Ecotoxicology and Environmental Safety*, 75,19-24.

Gheisari, S., Danash, S and Torghabeh, J.A. (2009). Vermicompost potential in recycling of herbage waste. *Natural resources and Agricultural sciences*, 16(2).

Haimi, J., & Huhta, V. (1987). Comparison of composts produced from identical wastes by vermistabilization and conventional composting. *Pedobiologia*, 30,137-144.

HMGN/JICA. (2005). Pilot Project: Medium-Scale Vermi Composting of Vegetable Market Waste in Kathmandu Metropolitan City. Clean Kathmandu Valley Study.

Hanc, A., & Vasak, F. (2015). Processing separated digestate by vermicomposting technology using earthworms of the genus *Eisenia. In J Environm Sci Technol,* 12,1183-90.

Huang, K., Li, F., Wei, Y., Chen, X., & Fu, F. (2013). Changes of bacterial and fungal community compositions during vermicomposting of vegetable wastes by *Eisenia foetida*. *Bio resource Technology*, 150,235-241.

Jackson, M.L. (1967). *Soil chemical analysis* (pp 205-498) New Delhi: Prentice Hall of India, Pvt. Ltd.

Jafarpour, M., Pessarakli, M., & Kazemi, E. (2017). Effects of Raw Materials on Vermicompost Qualities. *Journal of Plant Nutrition.*

Kaur, S., Kour, G., & Singh, J. (2014). Vermicomposting of tea leaves waste mixed with cow dung with the help of earthworm *Eisenia fetida. International Journal of Advanced Research in Biological Sciences,* 1(9),229-234.

Kaushik, P., & Garg, V.K. (2003). Vermicomposting of mixed textile mill sludge and cow dung with epigeic earthworm *Eisenia foetida*, *Biores. Technol*, 90(3),311-316.

Kayastha, S.P. (2014) *Soil Analysis.* Kathmandu: Peoples Print House Pvt.

Kumar, V., & Singh, K.P. (2001). Enriching vermicompost by nitrogen fixing and phosphate solubilizing bacteria. Bioresource Technology, 76,173-175.

Lee, K.E. (1992). Some trends opportunities earthworm research or Darwin children. The future of our discipline. *Soil Biology Biochemistry*, 24,1765-1771.

Liang, C., Das, K.C & McClendon, R. W. (2003). The influence of temperature and moisture contents regimes on the aerobic microbial activity of a bio solids composting blend. *Bio resource Technology*, 86,131-137.

Ludibeth, S.M., Marina, I.E., & Vicenta, E.M. (2012). Vermicomposting of Sewarage Sludge: Earthworm Population and Agronomic Advantages. *Compost Science & Utilization*, 20,11-17.

Mahaly, M., Senthilkumar, A.K., Arumugam, S., Kaliyaperumal, C., & Karupannan, N. (2018). Vermicomposting of distillery sludge waste with tea leaf residues. *Sustainable Environment Research*, 28,223-227.

Manaig, E.M. (2016). Vermicomposting Efficiency and Quality of Vermicompost with Different Bedding Materials and Worm Food Sources as Substrate. *Research Journal of Agriculture and Forestry Sciences*, 4,1-13.

Mehta, N., & Karnwal, A. (2013). Solid waste management with the help of vermicomposting and its applications in crop improvement. *Journal of Biology and Earth Sciences*, 3(1),B8-B16.

Mitchell, A. (1997). Production of Eisenia foetida and vermicompost from feed-lot cattle manure. *Soil Biology and Biochemistry*, 29,763-766.

Mousavi, S.A., Faraji, M and Janjani, H. (2017). Recycling of three different types of rural wastes employing vermicomposting technology by *Eisenia fetida* at low temperature. *Global NEST Journal*, 19.

Muthukumaravel, K., Amsath, A., & Sukumaran, M. (2008). Vermicomposting of vegetable wastes using cow dung. *E-Journal of Chemistry,* 5,810-813.

Okalebo, J.R., Gathua, K.W., & Woomer, P.L. (2002). Laboratory methods of soil and plant analysis: a working manual second edition. *TSBFCIAT and SACRED Africa, Nairobi, Kenya*.

Olsen, S.R., Cole, C.V., Watanabe, F.S., & Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *US. Department of Agriculture Circle*, 9, 39.

Pattnaik, S., & Reddy, M.V. (2010). Nutrient Status of Vermicompost of Urban Green Waste Processed by Three Earthworm Species- *Eisenia fetida, Eudrilus eugeniae, and Perionyx excavates*. *Applied and Environmental Soil Science*, Hindawi Publishing Corporation, 1-13.

Pourzamani, H., & Ghavi, M. (2016). Effect of rice bran on the quality of vermicompost produced from food waste. *International Journal of Environmental Health Engineering*, 5,13.

Rupani, P.F., Mohd, F.M.D., & Zelam, D.K. (2013). Sustainable management of different organic waste by vermicomposting technology. *Journal of Agricultural Technology*, 9(3),529-539.

S, K.K., Ibrahim, M.H., Quaik, S., & Ismail, S. (2013). Vermicompost, Its Applications and Derivatives. *Prospects of Organic Waste Management and Significance of Earthworms*, 199-130.

Shah, M.N., Gajalakshmi, S., & Abbasi, S.A. (2013). Direct Vermicomposting of Vegetable Waste Using the Concept of High-rate Vermireactor Operation. *International Journal of Environmental Science and Engineering Research (IJESER)*, 4(3),59-65.

Sharma, K. (2003). Municipal solid waste management through vermi-composting employing exotic and local species of earthworms. *Bioresource Technology*, 90,169-173.

Shrivastava, S., & Singh, K. (2013). Vermicompost to Save Our Agricultural Land. Research *Journal of Agriculture and Forestry Sciences*, 1(4),18-20.

Sinha, R.K., Agarwal, S., Chauhan, K., Chandran, V., & Kiranbhai, B. (2010). Vermiculture Technology: Reviving the Dreams of Sir Charles Darwing for Scientific Use of Earthworms in Sustainable Development Programs. *Technology and Investment*, 1,155- 172.

Unito, G. L. (2023). Nutrient analysis of vermicompost using different feeding media. *AGBIR,* 39(4),678-681.

Walkley, A.J., & Black, I.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*, 37,29-38.

Yadav, A & Garg, V.K. (2011). Recycling of organic wastes by employing *Eisenia fetida*, *Bioresource Technology,* 102,2874–2880.

Yadav, J., Gupta, R.K., & Kumar, D. (2017). Changes in C:N ratio of different substrates during vermicomposting. *Ecological Environment and Conservation*, 23(10),368-372.